Yellowstone Science

A quarterly publication devoted to the natural and cultural resources

A Chat with a Grizzly Bear Expert
Carrion Beetles and Biodiversity
Observing Yellowstone Otters

Volume 6 Number 1

Photo courtesy IGBST.

The Legacy of Research

As we begin a new year for *Yellowstone Science* (the journal and, more important, the program), we might consider the value of the varied research undertaken in and around the park. It is popular in some circles to criticize the money we—our society, not just the National Park Service—spend on science. Even many of us who work within a scientific discipline admit that the ever-present "we need more data" can be both a truthful statement and an excuse for not taking a stand.

Researchers themselves are often prone to apologize for not being able to give definitive answers to what may *seem* like simple questions. How many species are there in Yellowstone? How abundant is each one? Should there be more, and what can we do to make it so? Our eagerness to learn and to do right in our mission to conserve the park's component species and ecological processes makes us anxious to *know* with certainty. But scientific understanding comes slowly, often with painstaking effort.

As a graduate student I was cautioned that my goal should not be to save the world with my research, but to contribute a small piece of knowledge from a particular time and place to just one discipline. I recalled this advice as I spoke with Nathan Varley, who in this issue shares results of his work on river otters, about his worry that he could not definitively comment about their abundance. Otters have not previously been studied here, and his observations of their behaviors and distribution are a valuable contribution to Yellowstone science.

Sandwiched between two stories of popular favorites is Derek Sikes' article on carrion beetles. His fascination with the often-overlooked invertebrate fauna comes through with humor as he reminds us how much we have yet to learn about the complex interactions among species, big and small. Studies of non-charismatic creatures and features are as vital to our understanding the ecosystem as those of megafauna.

For 24 years, Dick Knight studied one of Yellowstone's most famous and controversial species. With a bluntness atypical of most government bureaucrats, he answered much of what we demanded to know about grizzly bears, never seeking the mantel of fame or limelight that often falls easily upon biologists who study endangered species. At the end of his career he marvels at how much there is still to learn, and leaves us with a rich legacy of research added to the body of knowledge about grizzly bears. For myself and for many others who value the wild creatures of Yellowstone, I say thank you, and farewell.

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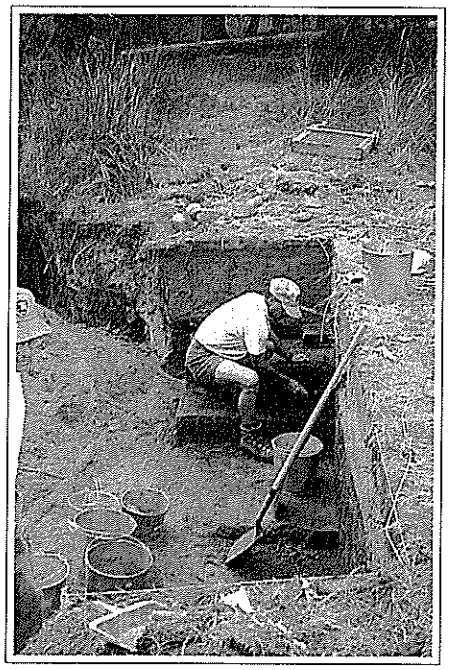

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On the cover: Otter pup. See related story on page 15. Photo courtesy Nathan Varley/Landis Wildlife Films. Above: Archeological fieldwork in Yellowstone. See page 20. Photo courtesy Mack Shortt.

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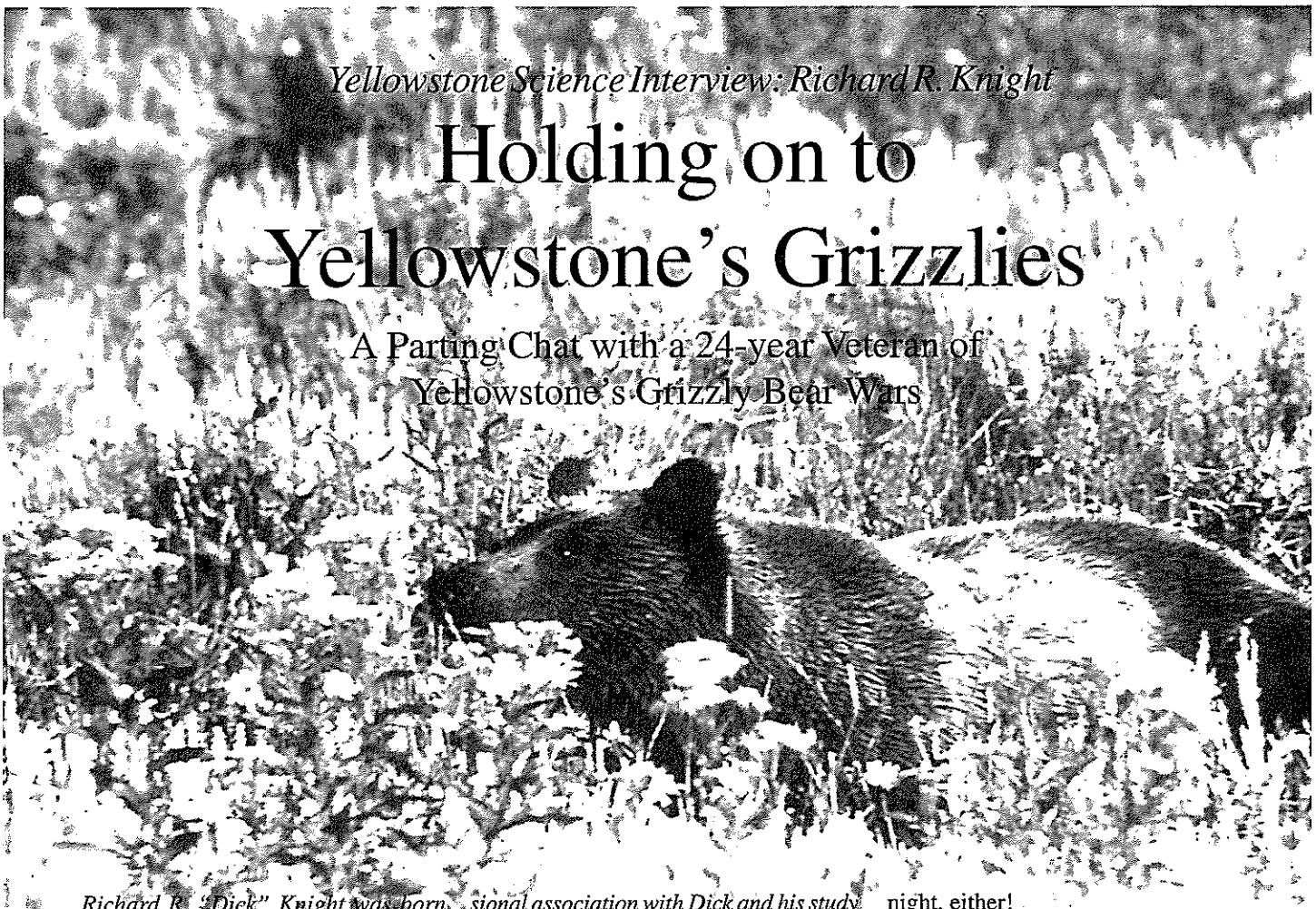
Yellowstone Science Interview: Richard R. Knight

Holding on to Yellowstone's Grizzlies

A Parting Chat with a 24-year Veteran of Yellowstone's Grizzly Bear Wars



Richard R. "Dick" Knight was born in Wyoming and raised in Montana, where he earned bachelor's and master's degrees in wildlife biology. After earning a Ph.D. studying Montana's Sun River elk herd, he was teaching at the University of Idaho when he was lured away. He became the first—and until his retirement in September 1997, the only—head of the Interagency Grizzly Bear Study Team (IGBST), created in the aftermath of a stormy parting between Yellowstone National Park and brothers Frank and John Craighead, who studied grizzly bears in the park from 1959 until 1969. Dr. Knight has published numerous papers on the grizzly bears of Yellowstone and advised managers through thorny controversies since the population was listed as "threatened" under the Endangered Species Act in 1975. He was interviewed for Yellowstone Science *in August of 1997 by the editor and John Varley, Director of Yellowstone's Center for Resources, both of whom have had a long professional association with Dick and his study team.*

YS: How did you get started studying bears?

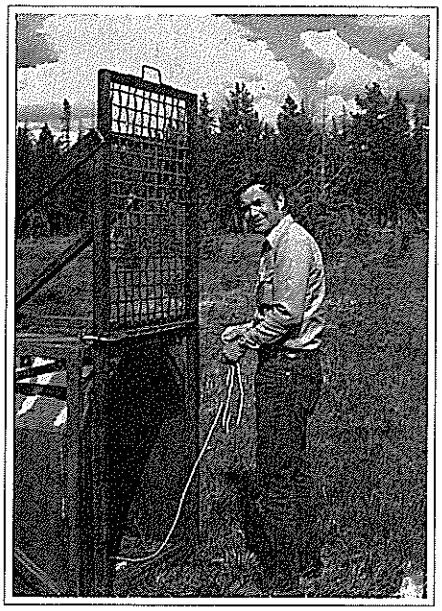
DK: Well, I was tired of teaching. I wanted to get back in the field. I had a lot of contact with bears when I was in the Bob Marshall Wilderness Area in Montana. I was slated to do a grizzly bear study up there, after I was done studying elk and sheep and deer; we never got around to it.

I first started working for Glen Cole [*supervisory research biologist for Yellowstone National Park from 1969 to 1975*] in Montana, so we're old friends. When I was in Idaho I kept bringing field trips to Yellowstone every year, and I'd have dinner with Glen and Gladys and we'd talk about old times. We had an argument in spring 1972, something to do with natural regulation, and some assumptions that he was making that I didn't think he could make. He just got mad—I didn't get invited to dinner that night, either!

So I didn't hear from him until probably August, and he called me up and [said] "Gladys and I were wondering where we'd like to go for Labor Day...and she says, I'd like to go over and visit the Knights in Moscow, Idaho." I said, "Well, the steelhead fishing's good, come over." And I turned to my wife and said "Something's wrong in Yellowstone Park, because Glen never goes anyplace for pleasure; there's something up." The grizzly bear job was coming open, and Glen came over and said, "We've got this position, and I want you to apply for it."

YS: Did you see changing from waterfowl and ungulates to bears as a career shift, or as fish biologists would when moving from grayling to trout? Were you aware of how controversial it was?

DK: It's just a different animal to work on. If I had known what the next five years were going to be like, I'd still be running the other way! I'd been through a lot of controversies and stuff...but the feds—people stab you in the back for



Dick Knight setting a bear trap. Photo courtesy Bonnie Blanchard.

practice! I wasn't used to all that.

First, I didn't know who was supervising me. No one was—no one really ever has—but I was reporting to Washington, D.C., and I was supposed to be working for Nathaniel Reed [*Assistant Secretary of the Interior in 1973*]. Eventually I was reporting to the National Park Service's (NPS) chief scientist, then they reassigned me to Bay St. Louis, Mississippi, then Denver, and finally, on paper at least, to Yellowstone National Park.

YS: Did you get much direction in the beginning about your mission and that of the new concept—an independent group of scientists from various agencies, working together to study the ecosystem's grizzly population? Was this on the heels of the National Academy of Science's review of the Craigheads' data and the Park Service's reinterpretation of it? *[Ed. note: The rift between the NPS and the Craigheads was largely due to disagreement over whether to abruptly close park garbage dumps, where bears had fed for decades, or to phase the dumps out and wean the bears slowly back to natural foods. It was a time when NPS policy was moving toward what is now called "natural regulation." Debate over what percentage of the bears relied upon the dumps and the size of the ecosystem's grizzly population ultimately led to a National Academy of Science (NAS) review of the grizzly bear data.]*

DK: This was before that started in 1974; I'd been here a while. We'd have these meetings, of a steering committee which was like the IGBC [*the present day Interagency Grizzly Bear Committee, made up of senior agency managers*]; it had six agencies, and I had advice like you couldn't believe. I had Starker Leopold and Durward Allen putting in their two-cents worth; you had to take their thoughts seriously. These people had great ideas on what to do—I've got a list of them someplace—it's about a foot long of things to look at, with $47,000 in the budget!

YS: Did that include your salary?

DK: Yep! So I just went ahead and decided what to do. Of course, we couldn't do much since we weren't allowed to tag bears to start with, but we just designed a study and did it. Once a year I'd report to the steering committee and they'd spend most of two days fighting with each other. First it was about whether the bears would be listed or not. The states would be fighting with the feds, and the Forest Service would fight with the Park Service and the Fish and Wildlife Service. About the last half-day, they'd say, "What have you been doing, Dick?" And I'd tell them and I'd go my way for another year.

YS: Wasn't each state and federal land or wildlife management agency in the ecosystem to help fund the IGBST?

DK: The original deal, made in West Yellowstone in 1972, was that everybody would contribute money and a person, and everybody would hire a new biologist that wasn't part of their outfit to become part of the team. Actually, the Park Service was the only one that hired somebody new. Of course, they had to keep the deal, 'cause Nat Reed was overseeing all this stuff. The Fish and Wildlife Service transferred in one of their guys who had just finished another project, and the same with the Forest Service. Wyoming took Larry Roop, who was working with their magazine at that time, and they put him on the team. Montana assigned Ken Greer part time, and Idaho never assigned anybody. Nobody ever gave any money, except Wyoming. Of course, the Fish and Wildlife Service did support their person, and the park and the Forest Service did. After Joe Basile left the Forest Service, all we got was office space. And when Steve Judd left the Fish and Wildlife Service, they took his money to hire Chris Servheen, [*as Grizzly Bear Recovery Coordinator*]. Fish and Wildlife Service kept giving us $25,000 a year for quite a while, but a couple years ago they gave that up because they didn't have the money.

YS: Was it your idea or someone else's that stationed you in Bozeman, associated with the Montana State University campus, a bit removed from Yellowstone and the other land managers?

DK: You know how that happened? At the International Association of Fish and Game Commissioners in 1974, they decided to have a committee on grizzly bears. They said they didn't see how Dick Knight could be objective, since he was right in Yellowstone Park. So, Nat Reed said, "We'll move him to Montana State University." And that was it. I didn't know about it until my boss called me and said, "We're moving you up to Bozeman." I said, "I can't afford to move to Bozeman." He said, "We'll promote you." But the promotion took almost 20 years!

YS: So you were supposed to study bears and you had almost no money, and you couldn't touch them? Why was that? Weren't, if I recall, the "green groups" against trapping and collaring any bears at that time?

DK: There was opposition from all kinds of people. Even some government people were against it because the Craigheads had tagged bears and used radiotelemetry, and they didn't want anything to do with anything the Craigheads had done. So I couldn't radiocollar bears.

We were interested in assessing the population, but the only thing I could do for the first two years was collect bear scats and assess some habitat use. We'd see bears from observation flights and record that, but there was no way that we were going to get any good population data at all, because bears are hard to work with to start with—they're secretive and low density, and it's pretty tough.

I finally got permission to do trapping down at Yellowstone Lake inside the park. I had to use psychology...I went to Glen and [*park superintendent from 1967 to 1975*] Jack Anderson and said, "we've got these bears down there and I don't

know where they come from and what they do; the Craigheads didn't know anything about this." And they said, "Oh, the Craigheads didn't, eh? Well, maybe we *should* put a couple of radios on."

So that's the way it went. Every time I wanted to tag some bears, I'd write up a special project proposal. It took about five years, until about 1977, before we finally got a widespread trapping effort started.

YS: In 1975, when the grizzly was listed, the politics were rampant. Were the bears biologically endangered in your view?

DK: They probably were, but I didn't *know* it at that time. In 1974, when we first started talking about it, I said, "I haven't got any data to show one way or another whether they're threatened or not." Nat Reed got a little angry with me because of it, but hell, I couldn't tag, where was I supposed to get the data? But they listed them anyhow; it was done strictly on politics.

YS: Did you have any notion that listing—not the process of listing, but the fact that the bears were listed—would be as complicated as it is?

DK: No, I don't think anybody did. It was all new-the Endangered Species Act was new; it was a great thing.

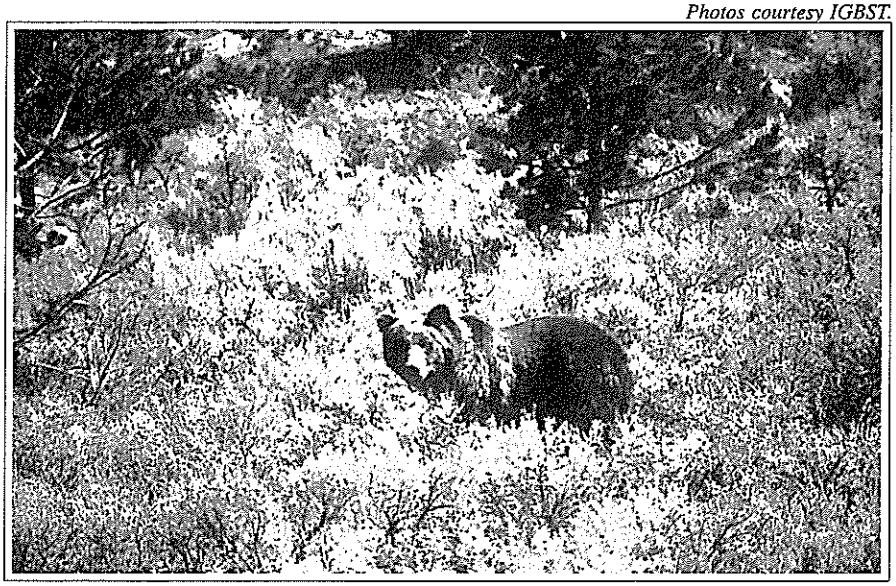
YS: Did you have access to the Craigheads' data when you first started?

DK: No. Well, I had all of their reports; they had publications, such as the one they came out with in 1974.

YS: Were the Craigheads right or wrong?

DK: Well, they weren't *all* right, and they weren't all *wrong*, either. By phasing the dumps out slowly, I believe it would just have caused more bears to learn to eat at dumps over a longer period of time, then they'd be fighting over what was available at the dumps—decreasing amounts of food. It wouldn't have done the bear population any good. So I think that closing the dumps abruptly was the way to do it. But that had a traumatic effect on the bear population, and the Park Service did not foresee all of what was going to happen. They should have had a big campground management and bear management program in place before they did it; a lot of bears just disappeared during that time. They weren't necessarily *killed*, but they were transplanted and never came back. Glen told me that bears would come into the campgrounds, and that they had an 83 percent success rate at transplanting bears. Well, we've *never* had that. You get an adult bear, it's pretty hard to move them far enough to where they don't come back. The only two adult bears we've moved successfully went to Canada.

Photos courtesy IGBST.



YS: Did you work outside the park much in those days, and did you see bears in Idaho, and in the Big Sky area of Montana—places where they are thought to be expanding today?

DK: Occasionally you'd get one in Idaho...in the early 1970s we had one in the Yellow Mules, and in Buck Creek, northwest of the park, but we weren't doing a lot of work over there. In Cabin Creek *[also on the Gallatin National Forest]* we did a lot of work, and we had a lot of bears in that area, which we don't have anymore.

YS: What do you suppose happened to them?

DK: People.

YS: People shooting? People just living?

DK: We hear rumors about people who have shot bears up there, but then it's just a pretty popular spot; a lot of people go through there.

YS: When I first came to Yellowstone in 1982, I'd hear "there aren't any grizzlies in the Tetons, it's safer to camp there, safer to hike." A friend of mine was a resource manager, and in 1986 he was pulling in non-bear-proof garbage cans at night from around the park housing area, because even the staff had the attitude that they didn't have to deal with grizzly bears. And he thought they were there. Were there grizzly bears in the Tetons the whole time?

DK: I think there were a few, not very many. Up around Berry Creek, in the northern end of Grand Teton National Park, there have always been grizzly bears. But they're adventurous and they move around, especially in a bad food year.

YS: We hear a lot today about a change in distribution of grizzlies, as well as an increase in bears. We sometimes even get told that we don't have more bears, they're just all leaving the park.

DK: Well, none of the radioed bears have left the park. We just have a big increase in bears in Wyoming—that's where they're going, that's where they've got the habitat. And Wyoming is really interested in bear management. We've lost bears on the west side *[of the park]*, I think.

YS: I remember the trappers taking grizzlies off of domestic sheep grazing allotments on the west side of the Tetons. Wasn't there quite a controversy when the Forest Service tried to eliminate sheep allotments?

DK: We were really involved in that. The Gallatin and Targhee *[national forests adjacent to Yellowstone]* supervisors just didn't want to believe that grizzly bears and sheep couldn't coexist. But we got the allotments out.

YS: So sheep and grizzly bears are truly incompatible?

DK: Well, it's the *herders* that are incom-

***YS:* So sheep and grizzly bears are truly incompatible?**
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YS: Early on, were you concerned about the levels of bear mortalities, either by park managers or by hunters? They were still legally hunting bears outside the park until 1975, when the bear was listed.

DK: I didn't know; you couldn't be concerned about mortality cause you didn't know what the size of the population was. We were removing bears inside the park when they got into trouble, because we didn't know any better. It had to be done. It wasn't until about 1980 that we had a suspicion that we didn't have as many bears as we'd thought. By 1982, I had the data to show it.

YS: What's the story behind the famous "Ro Wauer" memo? [*Ed. note: Wauer, a biologist from the NPS's Washington Office, wrote a memo about the grizzlies' declining population which prompted high-level concern and resulted in the agencies banding together to create the Interagency Grizzly Bear Committee (IGBC), which still operates today.*]

DK: I was talking to John Townsley [*park superintendent from 1975 to 1982*]; he'd been listening to me since 1980, but nobody else really was—it was just like the bear wasn't listed...We had enough data to show we had a declining population. And I went to Ro and said, "Look, we're going downhill fast and we've got to do something." And I gave him all the stuff, and he wrote that memo to the Steering Committee and leaked it to the press, and got transferred to the Virgin Islands for it! He was probably happy about it. But the upshot was, they created the IGBC, and the land managers started taking grizzly bear management seriously, specifically by targeting adult female mortality, really all mortalities.

YS: When the bear population was at a low point, I remember a huge debate over "saturation trapping" versus sampling. Can you explain the alternatives we were talking about and which you would have preferred to do?

DK: Sampling was going along the way we were, getting data at the same rate we were. With saturation trapping, you could get a whole lot of data at once, which would have been good. But you've still got 9,000 square miles of mountainous terrain to deal with, and where are you going to trap? You're not going to find the money; it's a great dream. Even now with the DNA sampling, you can't put that many baits out. And there weren't that many people working on bears at that time. We had five or six experienced bear trappers, maybe, in the U.S., and they were working for other people; they had jobs of their own. Saturation trapping just wasn't feasible.

YS: Then it became a big debate about how many female grizzlies you would trap and radio collar.

DK: That was the IGBC. It was 1983 when it began—that was the end of the Steering Committee—and IGBC took responsibility for all the bears in all ecosystems. There used to be an argument about how many bears we should trap. For a while they'd say, only trap females, so we'd only trap females and let the males go, but the next thing you know, they'd want me to make a population estimate. And I would say, "Well, you know, a population estimate includes males, and so we'd better start trapping males." Pretty soon, they let us scientists go our own way, and we did as much as we could; that's what we've always done—as much as we can with the money we've got.

YS: Were you involved in the park's effort that started about that same time, perhaps because of the memo, to write the *Grizzly Bear Management Plan*? In the paper trail, that's the first time we clearly said we have to limit bear mortalities, and we've got to get serious about some other things. We set up the bear management areas, called "human use adjustment areas" at the time, until Bob Barbee [*park superintendent from 1983 to 1994*] kept telling me to quit using that term; it just didn't sell well. What was the rationale behind the bear management areas?

DK: We had a lot of the rangers talk it over. They were some of the areas where we knew we had pretty good concentrations of bears, and those were the ones in which we restricted human use during specific times or areas—places like the Gallatin Range. It's one of our best cub-producing areas, and I was really adamant about getting that closed to off-trail traffic. People are still trying to get that opened back up. We took a field trip through there in 1993 or '94, a couple of park rangers and an outfitter and I, and we showed them what we were talking about. The wildlife there are different. When you see a couple thousand elk running away from you, in obvious panic, it makes a big impression.

Antelope Creek was an area that at the time didn't have a lot of bears but had a lot of people use, and it was an area we thought we could close off—that was the most successful thing we've ever done, that closure. Now it's a place people can go and see bears, and it wasn't that way before the park closed it.

YS: Some of the debate over grizzly bear management through the years has been about whether science and management were separate enough, or worked closely together enough. One of the criticisms from the Craighead days was that when the scientists were doing bear management, too, it affected their objectivity as data collectors and analyzers. Do you think that was true of you?

DK: No, I don't think so. I wasn't doing bear management; I was advising. We at the IGBST have always worked closely with the managers, especially the park. Some outside scientists think that when a publication would come out, the managers would have the data. I thought they probably should have access to this stuff as soon as you've got it. The quicker you use it, the better off you're going to be. I think that's been one of the big things that's been successful for the grizzly bear in Yellowstone—the fact that research and management worked closely together.

YS: Were you involved at all in the human fatalities caused by grizzlies, and did it surprise you when it happened?

DK: Well, in some of them, I was involved. It's always shocking when that happens, and in most cases, there's a rea-

son for it. But some of them, like Brigitta Fredenhagen in Pelican Valley in 1984 and the guy over in West Yellowstone [*William Robert May in 1982*]...boy, those were just unexplained; these were people that did everything right as far as we could tell. Some bears are just like that.

YS: You trapped how many bears in 20 years?

DK: We're at 289 or something.

YS: Were you ever in a situation where you thought your life was threatened by a bear?

DK: Well, with bear #25, which I had to kill. It was in 1977 over at Mack's Inn, in willows along the Henry's Fork at Island Park, Idaho, where many people were fishing. She had two cubs-of-the-year. Somebody living there shot her in the rear "in self-defense"—she was eating food on the porch—and also shot one of the "monster" 40-pound cubs. We knew she was wounded so we had to go check and see how badly, and see whether or not we could just leave her there, or what. Boy, she turned out to be not only fairly badly wounded, shot bad in the hindquarter, but also pretty feisty. We were only about 15 to 20 feet away and she just got up and charged us, and we didn't have any choice. You can tell a bear that's coming for you as against one that's bluffing you—in the same way you can tell a dog that'll do the same thing. You can tell if they mean business or not, and this bear was not bluffing. When they grunt like a pig, that's time to watch out, because their exertion means they are out to get you.

YS: Dick, a number of people have said that this project—your project—has the best database on brown bears in the world. That presumes that you know the most about them of anybody in the world. How would you characterize your study object? After looking at them for all these many years, what are they like?

DK: Well...they're just out there trying to make a living, like anybody else. They

are a very interesting animal; they're more fun to watch that an elk, or a deer, because they do have so many different kinds of mannerisms. And you never know what one's going to do next. There's an occasional bad apple, just like there are people—but there's probably fewer of them among the grizzly bear population, so to speak, than among people!

They're just trying to go their way and mind their own business, except that when it comes to food, that's a very *big* part of their business. And if you've got some, they'll want it! That's all. Once you understand, I don't think they're any more dangerous than any other animal.

YS: One time you told me, maybe a dozen years ago, that about the time you think you're ready to generalize about the grizzly bear, well, just wait until the next summer and they'll turn around and do something entirely different. They must be very versatile.

DK: That's right. And it's still true. They are very, very versatile. And they keep learning new tricks every year; we haven't seen them all yet. We've never had a year that was just like any other year, they're all a little bit different. All of a sudden the bears will come up with some new food item that they'll eat. And we've got some food items out there that they apparently haven't discovered yet.

"You can tell a bear that's coming for you as against one that's bluffing you—in the same way you can tell a dog that'll do the same thing. You can tell if they mean business or not, and this bear was not bluffing. When they grunt like a pig, that's time to watch out, because their exertion means they are out to get you."

YS: In the 1970s, greater Yellowstone was characterized as poor grizzly habitat. Do you still think that's the case?

DK: No, I don't think so. I think we thought it was poor because when you start looking at the lodgepole pine desert, so to speak, there's a lot of the ecosystem that isn't very productive as far as bear foods are concerned. But at times, it has a great mushroom crop and other things. Bears work mostly on microhabitats, and so there's always a bunch of little microhabitats in places, even in all that lodgepole, so they can find something to eat. Bears are learning more all the time how to use this habitat.

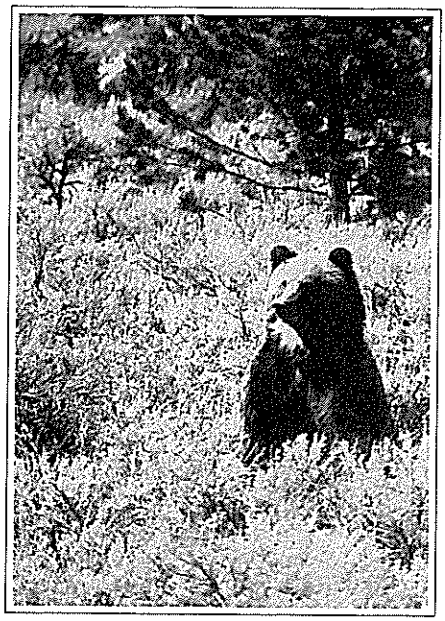
YS: Was it partly a matter of *our* learning, too? Did we think that bears ate berries, because that's what they were seen to do in other places, so we assumed that not having many berries made it poor habitat?

DK: Sure. I think a lot of their food habits were characterized from other places, and they'll eat almost anything.

YS: So, when one of our critics says we ought to get rid of all the elk so we can grow more berry bushes, how would you respond to that?

DK: I'd say that elk are a much better source of forage than berries. And the berries that would come back if all the elk were gone are not the kind of berries that bears eat anyway—snowberries, I mean. A snowberry is probably some of the stuff that elk are eating out; that probably hurts grouse but it doesn't bother bears any, because the elk are much better eating.

YS: I remember you saying that in the early 1980s you had seen grizzly bears stalk elk for the first time. Do you think



that was just part of your learning curve, or is there something to the notion that bears had forgotten a lot of natural foods in the days of the garbage dumps?

DK: I think they had, for at least summertime. But for a while, we think the only time they ever killed elk was when they were calves or during the rut, when bulls were really easy to catch. Then, sometime in the early 1980s they did start catching elk cows, in the middle of the summer. I can't remember which bear it was—bear #51, one of our big males—killed 13 cow elk one summer. He had a real ambush for them. Had a good time.

YS: Don't we have some that go after bull moose in the same way?

DK: Oh yeah. Moose aren't that much different than an elk, as far as a bear is concerned.

YS: Are bears individuals the way we treat human beings as individuals? You describe an elk predation specialist. I presume there's all different kinds of specialists. How do they discover new things?

DK: I think they've learned by watching other bears. Like fishing—it's something that's got to be learned; they don't just *know* how to fish. It's kind of funny. If you watch a bear that doesn't know how, they can see the fish and just jump right in with all four feet and come up empty. Then they go digging under the banks, and it just doesn't work. When they get the fish crowded, and the stream sort of dammed up, then the bears can get them. It takes a little bit of learning, but once they get it, they're really good at it.

YS: Are you optimistic or pessimistic for the future of grizzly bears?

DK: Sometimes I think they'll be around when we have overpopulated the earth. But I don't know, the way this country is going, the way it's developing...

YS: We hear a lot of concern over global warming and blister rust that will take out the whitebark pine. What about other threats like the lake trout and increasing development across the ecosystem?

DK: I think the worst I've heard for global warming is about a 5° shift, but that is not that much. Besides, you can't forget, we used to have grizzly bears in Mexico and Arizona and New Mexico, too. I think climate change is going to be gradual and the bears will adjust to it, if it's going to happen. That's going to be one of the things they have to cope with. Of course, they cope with no whitebark pine every now and then anyhow. So, it's just like every year is going to be a poor year, and they'd probably adjust. Now they've got the moths they can go on.

As far as lake trout are concerned, if they do cut into the cutthroat spawners significantly, well, that's going to cut into a food source, but then on the other hand, not all the bears in the park are fishing bears, either. There are other things to do.

YS: Do you think the bears can be "delisted" from Endangered Species Act protection?

DK: What I like to say is that I think the bear is recovered in Yellowstone Park and Wyoming, and probably endangered in Montana, and extinct in Idaho. That's the way it is, with the development in Montana...except for the Absarokas and north, it's really tough to see how bears are going to make it there. In Wyoming, I think they've definitely got a huntable population. But it's too bad that delisting removes all the protection of the Endangered Species Act. I can imagine people out there with chain saws and herds of sheep ready to move in when the bear population is delisted, and that scares me. Because I don't know how to protect habitat. We just don't know. You can write some laws, but hell, we couldn't protect the Targhee from widespread clear-cutting and road-building in grizzly habitat, even under the Endangered Species Act. You get an administrator who wants to get around a law, and he'll do it.

YS: If you were talking to the park superintendent right now, parting words on your retirement, what would you tell him to do or not do on behalf of bears?

DK: Just hold on. Hold on with bear management areas and keep developments down. Watch your garbage and indoctrinate new employees about bears—somebody new moves in, you start all over again.

YS: Is the big challenge more related to the bears' habitat than the population itself, in the next 25 years of grizzly bear management?

DK: As far as managing habitat, what can you do? If you can keep the roads out, that is the key. Access is a big thing, access and human development, encroachment on habitat.

YS: A lot of people think that greater Yellowstone will never be big enough, and that the lack of connectivity to another bear population is a concern genetically or demographically. What do you think about that?

DK: I'm not concerned about genetic isolation. It's another field where you've got all kinds of different experts arguing at all times. But we're talking 100, 200 years. Is the human race, civilization as we know it, going to be around that long? I'm not going to worry about 100 years from here, because who knows what will happen in that time.

As long as we can hold on to Yellowstone Park and those wilderness areas, we've got one of the best chances of anyplace in the world to hold on to grizzlies. We are in a lot better position than the NCDE [*the Northern Continental Divide Ecosystem in northwestern Montana*] where everything is broken up by all kinds of roads and people development. We've got a big chunk of habitat that's pretty much *protected* down here, and we've got one of the best shots of anyplace in the world, outside of Alaska.

YS: Do you see in the future real potential for use of such techniques as DNA analysis to help estimate a population or tell us other useful things?

DK: Sure, it's going to help us explain a lot. Whether we ever get to the point

where we are going to distantly make a population estimate out of it, I don't know, because the logistics of getting the samples is so great, but small portions of the population we could do.

It would get us lineage—this bear was related to that other bear that did that; okay, that explains that. Some of these things would be interesting; I don't know whether they would be particularly useful to management or not.

YS: Dick, I remember when the satellites were going to tell you everything you needed to know about grizzly bears and were going to count them.

DK: Well, Nat Reed was an ex-U2 pilot and he knew you could see things from 90,000 feet in the air. And Steve Mealey, who was working for me at that time, was an ex-intelligence officer with General Westmoreland in Vietnam. He knew those bears could be seen if they could see the Vietcong from the air, though a lot of the guys that were on the ground would disagree with him! I know these things *could* be done, but I didn't think we'd get the military to do it for us. What the military can do and what we can do are two different things. We hired an air service out of Salt Lake City to take some pictures, and I thought, it's gonna be hard to tell from the air, a long ways in the air, what you've got down there—there are a lot of bison, and I think they'd be hard to tell from bears. We put bear pelts out in Pelican Valley, and we *did* have one grizzly, over by Mary Bay, I think, that came out of the woods and sniffed the hide..."Who was this?"

The whole damn thing just flopped, like I knew it would. We could have spent that money on something *useful.* It was a really expensive little charade.

YS: When you look back at all your years of being in charge of the IGBST, what are your high moments?

DK: Just getting the data. I think the thing I'm most proud of is getting the agencies to cooperate with each other on bear management. Before that, Yellowstone Park would do one thing, Grand Teton another—they might have been on different planets. And every forest did things a different way...everybody was fighting with everybody, and of course, the states never got along with each other anyhow. But then, they had to come together, and the thing that's made it work is the cooperation among the agencies.

"...sometimes I think they'll be around when we have overpopulated the earth. But I don't know, the way this country is going, the way it's developing...we're talking 100, 200 years. Is the human race, civilization as we know it, going to be around that long?...

As long as we can hold on to Yellowstone Park and those wilderness areas, we've got one of the best chances of anyplace in the world to hold on to grizzlies. We've got a big chunk of habitat that's pretty much protected down here, and we've got one of the best shots of anyplace in the world, outside of Alaska."

YS: And this has resulted in tangible benefits to bears?

DK: Yeah, I think so, definitely. Like the IGBC. Everybody's working under the same rules for mortalities, and cooperation in transplanting bears.

YS: Is that telling about the wildlife management business, that the highlight of your long career here would be something that has to do with people?

DK: That's what wildlife management is all about. The animals get along pretty well. We go our way and manage this and manage that, and the animals go their way and survive the best they can.

YS: Maybe wildlife management ought to be populated with sociologists and psychologists and political scientists instead of biologists. Do you think professors are teaching that to wildlife management students? Did you, when you were teaching?

DK: No. You look at what happens out in the field, and what you teach in the classroom, and you begin to wonder, what am I doing? A lot of the stuff you teach them is obsolete. It's different now, you're talking about computers and statisticians; that's all you see in the *Journal of Wildlife Management*—it has very little to do with animals.

YS: Nowadays, whether the schools deliberately do this or the market does it, we've developed a cadre of "bear biologists," and "wolf biologists," and "fish biologists." Are there more specialists today?

DK: It may be. I always felt that a wildlife or fisheries biologist should be an *ecologist.* And the principles are pretty much the same for fish and animals.

YS: So what should your replacement be well steeped in?

DK: Getting along with people. Or at least, dealing with people. You don't especially have to get along with them, but you do have to deal with bureaucrats, politicians...The first five years were pretty tough, but I can look back and laugh now. On the whole, it's been a fairly enjoyable experience, a lot of fun.

YS: Do you think we have as many or more bears now as we had in the 1960s?

DK: I think there are more bears than in the 1960s. We've definitely got them scattered around in Wyoming and in the park.

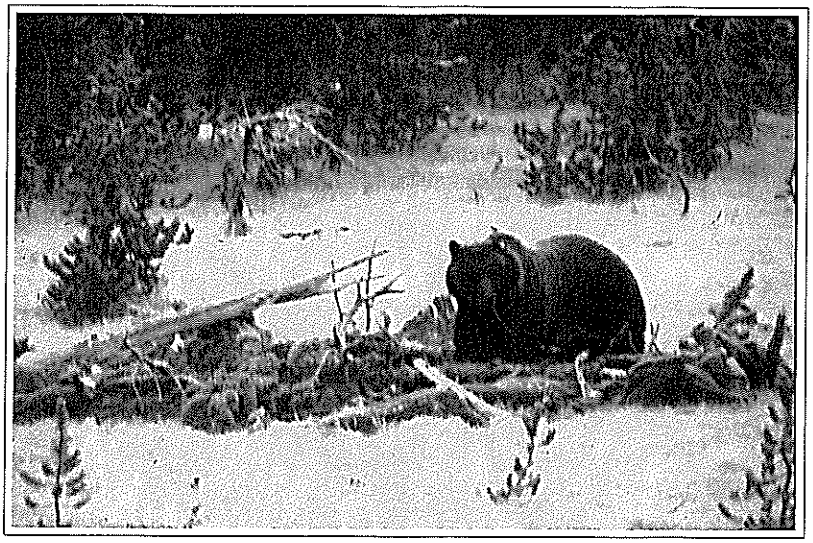
YS: And we don't need to go back to feeding them? Can you ever see circumstances when we might?

DK: No, I don't see that. We're trying to keep things as natural as we can. And these ungulates are a big food source, especially the elk, for bears. Especially in the early spring, the "overpopulation," so to speak, of elk that die and are so weak that they can't get away, are a big food source. No other bear population I know of has that particular food source. It's important to this group of bears.

YS: Do you ever see yourself writing the book on grizzlies or your life with them? You've laid low compared to a lot of the personalities that deal with endangered species.

DK: I just don't have that kind of personality. I'm not without an ego, but I don't have the kind that wants to write a book. And I'm tired of writing. I told Bonnie, [*Blanchard, his wife and coworker, who also left the IGBST in 1997*], when I retire, the checks are deposited—she has a checkbook; I'm not even going to write my name!

YS: You haven't always secretly thought,



Grizzly bear sow feeding on a five-point bull elk carcass.

I'm going to write the exposé when I'm retired and don't work for the government anymore—"kiss and tell?"

DK: No. I really have some strong feelings about some of the things that happened to me in the early times, and I don't have a very objective view of it, so I probably shouldn't write about it.

YS: That hasn't stopped lots of authors from writing!

DK: I know. If I ever wrote a book, I'd like to write about "Bears I Have Known"—just about fun bears; there have been a lot of those.

The one bear I liked, we call "Big Red." We never were able to trap him. He was in the Gallatins; the first time I ever saw him was on Fawn Pass. You could see him 'cause he was really reddish, his coat. We had a trap set up south of the pass in the meadow, and we used to pre-bait him. After about three times, here comes Old Red zooming out of the trees—the food plate is here! We did that a couple of times. Bonnie and I went up there to start trapping, and we got the horses, and the bait was all on the ground. I was in the trap putting the trigger bait on, and Bonnie says "here comes a bear!" So I came out of the trap and here comes Old Red, just ambling by—it's time he's going to have lunch. I shot a couple of times in the air. Bonnie said, "Let's get out of here." The horses were skittish, and I got on my horse, but then I said, "He's got all our trigger bait! All our bacon!" And so I ran back and I charged *him*, and grabbed the bait, and he ambled over and took the rest of it and ran for the woods.

I finished setting the trap and thought, boy, we'll have him in the morning! Nah, we caught some other little bear. We trapped several days in a row. Old Red, we never did catch him. We see him from the air now and then; he's still out there, at least as of a couple years ago. He's a big, big bear, one of the biggest bears we've got around.

YS: I'd like to go back and find some of bear #38's progeny. She was the bear that was purported to do everything—she was, as I recall, the most productive bear in the ecosystem at that time.

DK: Bear #38 lived over north of West Yellowstone, right where they want to put the golf course *[laughs]*, in the Fir Ridge area. She was really a good bear. Horse Butte and Cabin Creek, that was her area. One year, it was a great huckleberry year; I myself could smell the huckleberries at Two Top from Fir Ridge (and I was still smoking at that time.) She ended up taking her two kids over there to Two Top; I'm sure they went over there for the berries—but what did they find? Sheep! And it was great; they'd never had sheep before. But they did learn in a hurry, and we finally had to catch her and the kids, and she died on the way out. While she was tranquilized, her collar cut off the windpipe. That was a bad deal.

The first litter we knew she had was three cubs, and the next one was two, and she had another one before that, too; she was productive.

YS: Did other individual bears stand out, like the bear that disappeared for 20 years and then reappeared?

DK: That was a bear that we caught as a yearling over in Cabin Creek and just ear-tagged her; we couldn't put collars on then. About 20 years later we picked her up at Indian Creek. She'd been around all that time. We had another one that was killed over in Wyoming, in Mormon Creek. She had two cubs we ear-tagged and transplanted up in the south Absarokas, and we saw them the next year. We didn't see them for 17-18 years and then caught one down at Open Creek.

YS: Put yourself in the mindset of thinking you were just starting today and designing what you'd like to do in the next ten or twenty years. Would there be new and different things you'd suggest people research? Unanswered questions that you'd like to know about a grizzly bear, if you had more time and an unlimited budget?

DK: There are all kinds of things that I would like to know that you're never going to get money for and nobody is interested in studying—like moths. Bears feed on moths in high-elevation sites. Everybody wants to work on bears, but what is the life cycle of the moths? Where do those moths come from?

A lot of other supposedly insignificant species are kind of important to bears, and it'd be nice to know more about them. Why don't bears eat camas roots? Maybe they just haven't discovered them yet. And melica bulbs—we've got fields of melica bulbs out there, and the bears get them in pocket gopher caches, but they don't dig up melica bulbs. I had my troops go down and dig camas bulbs and melica bulbs, big bunches of them, and we sent them over to Charles Robbins *[professor of animal nutrition at Washington State University]*, and his bears just gulped them right down. Maybe it's something they haven't learned yet. And ladybug beetles—in other places those are a big deal. We've got them in the park, but bears haven't discovered where they congregate.

I really like bears. I think there should be a little bit unknown, a mystery about them, too.

Hidden Biodiversity

The Benefits of Large Rotting Carcasses to Beetles and Other Species

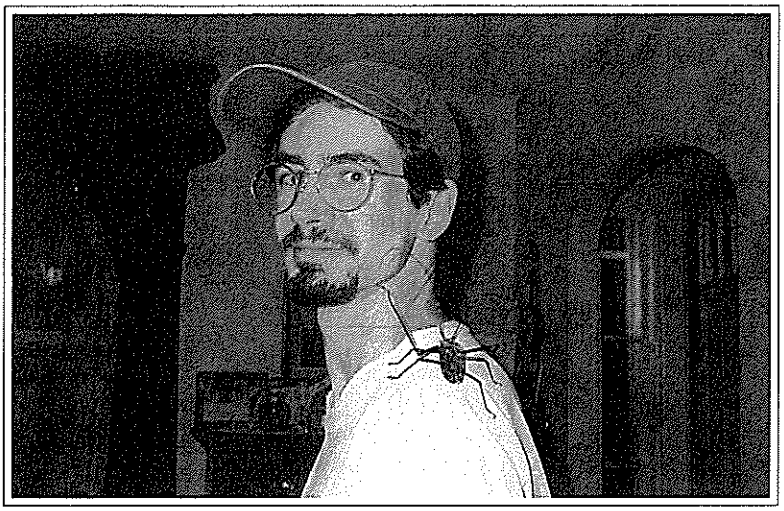


Photo courtesy of Derek Sikes.

by Derek S. Sikes

One late summer day in 1993, I was in the Lamar Valley as an alpine thunderstorm swept down toward me from the Absarokas. Like many other researchers, I was in Yellowstone because of my interest in its charismatic megafauna—its herds of elk and bison. But the three-month-old bison beside which I knelt was a carcass, little more than bones and yet teeming with life. As a graduate student at Montana State University, I had chosen for my master's thesis the task of describing beetles, a large portion of the Lamar Valley megafaunal food web. This project was based on two field seasons of data gathering, 1978 and 1993, and was completed in late 1994.

When considering all the species that constitute an ecosystem, it appears that some act as hubs of biodiversity, and have a disproportionate impact on the ecosystem's structure and functioning. Ecologists refer to these as keystone species. I like to think of them as representatives for hidden biodiversity—for the myriad often poorly known species whose abundances would change if the keystones were to disappear. Large mammal herds are obviously a significant component of the Yellowstone ecosystem. They consume large quantities of vegetation, produce large quantities of dung and carrion, and cause researchers to generate large quantities of data on mammalian ecology, behavior, and physiology. Although we may know what these animals eat, we know very little about what eats them.

How many species are linked to the megafauna found in the Lamar? We can list the 10 or so species of vertebrates that feed on ungulates there, but what about the hundreds of invertebrates? A complete list, you may be surprised to learn, would take years of research to finish. Conducting such research would improve our understanding of the Lamar Valley ecosystem by identifying some of the players. Managers of the Yellowstone ecosystem are interested in maintaining native biodiversity, so it is important to understand the values of having large rotting carcasses lying about.

My objective was to determine the effect megafaunal carcass communities have on the ecosystem of the Lamar by measuring changes in the beetle communities associated with them. Beetles are an especially diverse group of organisms and megafaunal carcasses are some of the largest, and in my opinion, the most exciting communities of ecological systems. It's possible that some of the same beetle species that I encountered during my study could have been found on a mastodon or glyptodont carcass 20,000 years ago. Although such speculation was beyond the scope of my research, by studying the beetles of the carrion community I could at least investigate a large portion of the species linked to Yellowstone's current megafauna and a largely unknown component of North American megafaunal biology.

Why Study Beetles?

The background for my thesis research began in 1978, when there was a large winter die-off of elk on Yellowstone's northern range. Dr. Robert Moore of

Montana State University initiated a project to understand the arthropod fauna associated with elk carcasses by sinking cups into the ground (called pitfall traps) around the carcasses to catch arthropods for later identification. He also set control traps 40 meters from the carcasses to compare the carrion-associated arthropods with those of the background habitat and to quantify the degree of association between beetle species and the carrion.

My advisor, Dr. Michael Ivie, has been conducting a larger but similar study using more than 800 beetle species to assess the effects of the 1988 fires in Glacier National Park. Beetles are frequently chosen as a focus of study because of their enormous numbers and diversity. Beetles are the largest order of life on Earth, outnumbering in described species even nematodes, bacteria, and the entire plant kingdom, and include one-third of all animal species that have been described on our planet. Coleopterists have named between 350,000 and 400,000 beetle species since 1758, at an average of about 2,300 new species each year during the last decade. However, that is only a small portion of the recent estimates, based on studies conducted in the tropics, of perhaps as many as 2.4 million beetle species that may occur on Earth. At the current rate of description, coleopterists will need another 870 years of exploring, discovering, and describing before the job will be complete!

Beetles feed on virtually everything and live virtually everywhere, from the bottom of lakes to the tops of trees, feeding on fungi, rotting wood, living wood, living vertebrates, leaves, stems, seeds, pollen, arthropods, dung, and, of course, carrion. Some species are generalists and feed on a wide variety of resources, while others have a strict diet, often specializing on a single species of plant or animal. Because of this ecological diversity, beetles are proving to be excellent indicators of environmental change. Mike Ivie has stated it nicely: "It's almost impossible for an ecosystem to be disturbed and not have an effect on the beetles that are in it."

The combined influence of Dr. Moore's initiative, my advisor's support, and my fascination with beetles led to my predicament that summer day—the storm and its lightning were approaching, and it had begun to get dark. I carefully poured the trapping preservative through a filter to extract the beetle specimens, trying not to spill any in my anxious haste. I knew grizzly bears commonly fed on carrion and was little comforted by either the anti-bear pepper spray in my pocket or the words of my advisor: "You must label your specimens promptly; that way, if you die, you will not compromise their scientific value."

Nature's Clean-Up Crews

My study focused on decomposition ecology, nature's clean-up crews. The decomposers, known as detritivores, channel more energy flowing through ecosystems than do herbivores and predators (Fig. 1). This makes sense when you consider that the decomposers consume all the dead plants, dead herbivores, dead predators and all of their wastes—that's a lot of consumption! Yet little research has been done on decomposition ecology in comparison to herbivore and predator ecology.

The grass emerging from beneath the bison carcass before me was both taller and greener than that surrounding it. The most obvious life-form using the energy stored within the remains of the bison was the immature form of *Thanatophilus lapponicus*, the northern carrion beetle. These small, six-legged creatures, protected by an exoskeleton composed of chitinous armor plates, were visible on every portion of the bison remains. As I knelt there collecting a sample of organisms that had blundered into the four pitfall traps placed around the carcass, I thought about bison and the connectivity of life. What percentage of Yellowstone's bison biomass is annually converted into beetle biomass? How many visitors or rangers realize that the molecules that make up a beetle they see

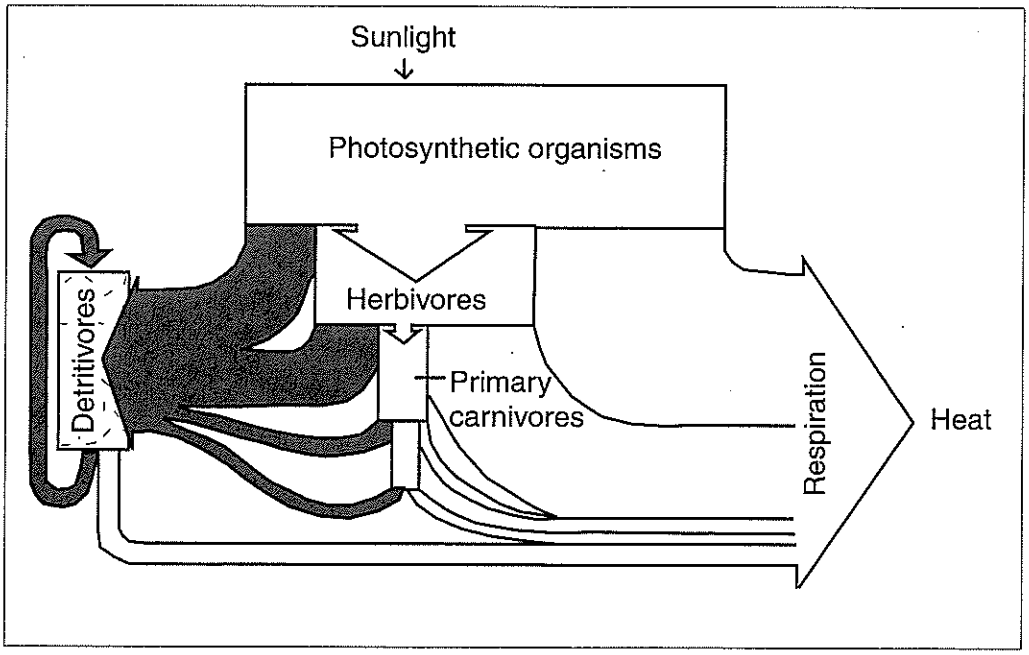


Figure 1. Energy flow through a typical terrestrial ecosystem. The darkened areas represent death (necromass) and waste products, all of which are processed by the detritivores.

may have recently been part of a bison?

Douglas B. Houston, a researcher familiar with the northern range of Yellowstone, found that during a period of three winters (1974–1978), about 75 to 80 percent of the total necromass (between 19,000 and 35,000 kg [77,161 lbs.] of meat) from 1,084 elk carcasses was eaten by vertebrate scavengers: coyotes, bears, and birds. Ten bird species (ravens, black-billed magpies, golden eagles, bald eagles, chipping sparrows, Audubon's warblers, western tanagers, mountain bluebirds, robins, and Brewer's blackbirds) were observed to feed on ungulate carcasses or the insects associated with them. These vertebrate scavengers, although consuming the majority of the necromass, are only the tip of the species-diversity iceberg. The majority of the diversity, perhaps as great as 90 percent, is composed of organisms that are often overlooked due to their small size. It was this hidden biodiversity on which I focused my research. Somehow these seemingly barren bones in front of me were producing pounds of beetle larvae—and I was capturing only those that fell into my traps.

As it turned out, I completed the collection rounds, got very wet from the storm, heard some of the loudest thunder in my life, and later successfully changed the numerous small beetles, carefully stored and labeled, into one sample period of thesis data. Each sample represented the catch of one trap, active for one period (*ca.* seven days). In total there was an effort of 194 days of trapping and the equivalent of 6,832 trap-days (one trap-day = one trap open for one day). Along with many other sample periods, including Dr. Moore's 1978 data, these data were subjected to statistical tests and analyses to quantitatively describe some of the puzzle pieces of the Lamar Valley carrion community.

Winterkilled bull elk.

Carrion Beetles' Abundance and Diversity

In Dr. Moore's 1978 field season, six elk carcasses were studied. Because of that winter's large die-off, the scavenger community had been sated and the carcasses lay virtually intact throughout the summer. In 1993, conditions were at the extreme opposite end of the spectrum; those few carcasses that were available had been stripped to bones within a week. I found one elk carcass and one bison carcass. From the beetles collected during these two seasons, I counted and identified a total of 23,365 adults of 445 species. Of the 445 species, there were 385 that were part of the quantitative data set and were thus available for statistical analysis. These were used to determine the effect of carcasses on beetle communities. Of the 385 species, 37 were strongly associated with carcasses in 1978 (Table 1), and 42 were strongly associated with carcasses in 1993. When both years' data were combined there were 57 carcass-associated beetle species. Eleven species were strongly associated with the control traps (apparently avoiding the carcasses), and 317 species showed no preference.

Thanatophilus lapponicus was the most common beetle in my samples, but it was only 1 of 57 species found in association with carcasses that can be considered the core of the Lamar Valley carrion-associated beetle community. However, not all of these species feed directly on carrion; the adults of many species prey on other arthropods. One such species, *Aleochara verna*, is a type of predator called a "parasitoid" that is not found among vertebrate species. It has an unusual life cycle that strongly resembles that of the monster in the science fiction movie *Alien*: the female adults pierce the skin of living fly larvae (maggots) and deposit their eggs within the larval tissues, where they quickly hatch into beetle larvae (grubs) that slowly consume the living maggot from the inside out, eventually causing its death. Also common in the carcass samples were beetles of the family Ptiliidae that are so small (less than 2 mm long [0.08 inches]) that they are thought to feed on fungal spores and other microscopic organic matter.

I was puzzled by the abundance of an herbivorous weevil species, *Otiorhynchus ovatus* (the strawberry root weevil, introduced from Europe), in the carcass traps. Could the great flush of nitrogenous compounds leeched from the carcasses that fertilized the surrounding plants have increased the survivorship of this weevil's larvae at the site? Or perhaps the abundance was a result of the higher humidity of the microhabitat, or a combination of both factors. Such an explanation doesn't require the weevil to prefer carcasses—the observations of abundance may have simply resulted from the fact that more individuals survive on carcasses than elsewhere. It would be a remarkable discovery if it could be shown that this plant-feeding weevil does actively choose carcass sites for breeding—an unlikely but interesting hypothesis because, to my knowledge, none of the 60,000 known species of weevils are carrion-associated.

Table 1. Carcass associated beetle species, 1978. Total abundances of 37 beetle species. The *P*-value represents the likelihood of obtaining such results if there were no differences between the carcass and control traps (i.e., if carcasses did not affect the beetle's behavior).

Species	Abundance in carcass traps	Abundance in control traps	Chi^2	*P*
Thanatophilus lapponicus (Hbst)	467*	1	360.0	0.000
Dermestes talpinus Mannerheim	144*	2	106.4	0.000
Anaspis rufa Say	188	18	102.5	0.000
Creophilus maxillosus (L.)	129*	0	100.0	0.000
Saprinus oregonensis LeConte	133*	2	97.9	0.000
Ptiliid sp. 4	126*	5	84.8	0.000
Trachypachus holmbergi Mann.	201	33	83.4	0.000
Omaliinae sp. 8	84*	0	65.3	0.000
Catops basiliaris Say	78	1	57.9	0.000
Trox sonorae LeConte	70*	0	54.4	0.000
Notoxus serratus LeConte	70	1	51.7	0.000
Necrobia violacea L.	58*	0	45.1	0.000
Staphylinidae sp. 65	66*	3	43.5	0.000
Dermestes fasciatus LeConte	50*	1	36.1	0.000
Staphylinae sp. 7	46*	0	35.7	0.000
Otiorhynchus ovatus (L.)	213*	79	33.0	0.000
Aphodius fimentarius (L.)	42	0	32.6	0.000
Oxytelus sp. 18	37	0	28.7	0.000
Saprinus lugens Erichson	36*	0	28.0	0.000
Staphylinidae sp. 80	28	1	19.1	0.000
Staphylinae sp. 5	24*	0	18.6	0.000
Anchicera sp. 2	23*	0	17.9	0.000
Omosita inversa LeConte	20	0	15.5	0.000
Borboropora quadriceps (LeC.)	19*	0	14.8	0.000
Encimus mimus Fall	19*	0	14.8	0.000
Corticarina cavicollis (Mann.)	22*	1	14.5	0.000
Staphylinidae sp. 63	17	0	13.2	0.000
Staphylinae sp. 4	13*	0	10.1	0.001
Staphylinidae sp. 72	16	1	9.9	0.002
Anotylus sp. 17	10	0	7.8	0.005
Tachinus basalis Erichson	9	0	7.0	0.008
Staphylinidae sp. 64	9	0	7.0	0.008
Cryptopleurum minutum (Fab.)	8*	0	6.2	0.013
Syntomus americanus Dejean	14*	3	4.7	0.030
Xantholininae sp. 43	6	0	4.7	0.031
Apteroloma tenuicorne LeConte	25	9	4.1	0.043
Falagria dissecta Erichson	5*	0	3.9	0.049

* 22 of 37 species that were also found to be significantly associated with carcasses in 1993.

Another puzzling find was that certain beetle species common in the 1978 sampling were not found in 1993 at the same sites. This may have resulted from changes that occurred during the interim, such as those due to the 1988 fires, but I cannot rule out other possibilities. Some species do show tight association with particular sites. For example, a small rove beetle (family Staphylinidae) in the genus *Bledius* (Fig. 2) that occurs in saline environments was found only at a site near Trumpeter Lake; these beetles dig burrows into the shoreline mud in which to rear their young. There were also beetles about which virtually nothing was known, such as those in the family Scraptiidae, that were shown to be carrion-associated.

Research Implications

I clearly demonstrated that a significantly larger abundance and diversity of beetles can be trapped adjacent to carcasses than are found 40 meters (131 feet) away (Fig. 3). For those who would ask "So what?" there are two reasons why these findings are important. First, previous carrion ecology studies had not quantitatively described the strengths of associations for the species studied. This novel and more rigorous approach has proven to be a powerful way to understand these systems in great detail. The second reason, perhaps of greater importance, is that to understand an ecosystem's biodiversity you must know its components. Currently, we are famil-

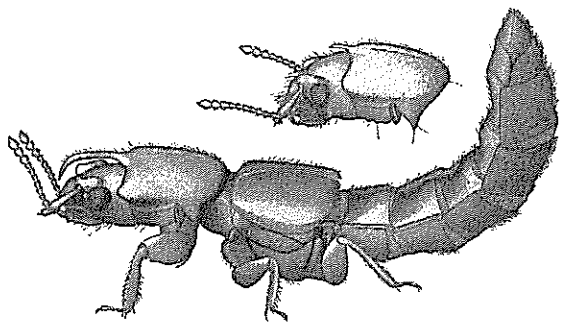


Figure 2. Bledius susae. *A close relative of 1 of the 445 beetle species found in the Lamar Valley.*

iar with very few of the components of the Lamar Valley megafaunal community.

In 1994, ecologist Truman Young reviewed the literature on large mammal die-offs applicable to wildlife conservation. (A die-off was defined as a rapid peak-to-trough decline of 25 percent or more in estimated population numbers). According to Young's analysis, these large die-offs should be considered a natural part of the species' population dynamics. Given the potential biomass and energy made available by a large mammal die-off, such as a 30 percent loss in a herd of bison, it seems reasonable to assume that such die-offs would play a role in many aspects of ecosystem functioning. No carrion study has directly compared a large die-off with the normal background density of carrion input, or compared the impact of large vertebrate carcasses (> 50 kg [110 lbs.]) to that of small ones. However, a reasonable hypothesis would seem to be that the greater the mass of carrion, the greater the richness, diversity, and ecological impact.

It has been estimated that during the Pleistocene, North America may have had densities of large mammals similar to those that can be found in the Serengeti of modern day Africa, which would mean that megafaunal carcasses were available in much greater numbers then. However, the Yellowstone ecosystem is probably as close as any researcher can get to studying the Pleistocene megafaunal ecology of North America without conducting paleontological research.

If a complete ecological understanding of the large mammal food web in the Yellowstone ecosystem is to be achieved, the list of species that are linked to the presence of these large animals needs to be completed. Houston's 1978 observations demonstrated that birds and bears were eating insect larvae from the skeletal remains of elk carcasses, indicating that the insects were a link in the chain between vertebrate scavengers and the carcasses (elk → carcass beetle → bear). My own research showed that many predaceous beetles are attracted to these carcass feeding frenzies, so the benefits of the dead elk and bison in the park can be traced through many links of an as yet little-understood food web. The trickle-down effects of dead ungulates are certainly greater than we currently recognize.

After all the parasites (ticks, lice, fleas, tapeworms, nematodes), dung-feeders (beetles, flies, fungi), predators (wolves, bears, cougars), and carrion-community members have been identified we will be prepared to determine their roles in this system in greater detail. Although to many it is a strange concept, we may someday look at these large mammals from a different, more complete perspective: that they are perfect habitat and resources for the many other (mostly invertebrate) species that together represent a greater portion of the total ecological value of the mammals themselves. How much biodiversity would vanish if the park lost its herds of megafauna? The herds themselves are composed primarily of fewer than five species; however, I can name 57 beetle species that might be greatly affected by such a loss. We must wait for future researchers to supply the remaining hundreds of species' names.

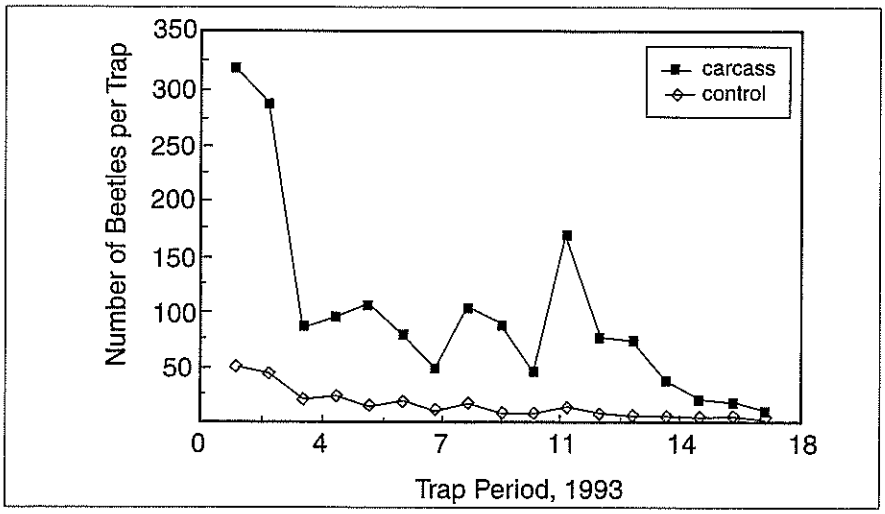
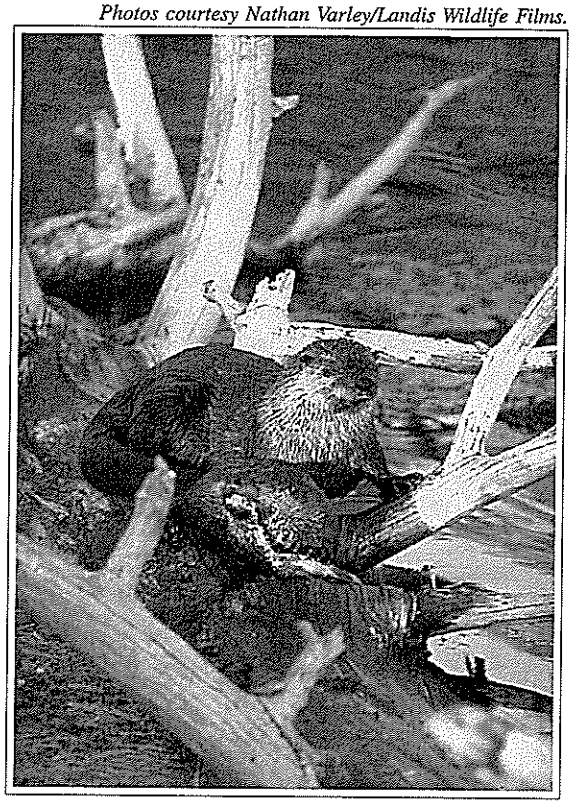


Figure 3. Distribution of beetle abundance over time, carcass and control trap data from 1993. Note that the final abundance of the carcass trap data is 12.7 beetles per trap and 5.8 beetles per trap for the control trap data.

Derek Sikes completed his master's degree in Entomology at Montana State University in 1994. He is currently working toward a Ph.D. at the University of Connecticut, revising the taxonomy of a behaviorally unique group of carrion beetles—the burying beetles. His interest in detritivores stems from undergraduate research he conducted on the natural history of a west coast species of burying beetle during 1991. Derek's research interests combine aspects of ecology, systematics, and conservation biology. In 1996, Derek fused research in these often disparate fields into a World-Wide-Web site, based on research conducted for the Connecticut Nature Conservancy (http://viceroy.eeb.uconn.edu/ctb/home.html), which includes taxonomic, ecological, and conservation information on Connecticut tiger beetles.

Photos courtesy Nathan Varley/Landis Wildlife Films.



Yellowstone's River Otters

Enigmatic Water Weasels

by Nathan Varley

The charismatic river otter (*Lontra canadensis*) is one of the most enigmatic members of Yellowstone's fauna. Since otters have not been studied extensively in the park, substantive questions exist regarding the local population status and ecology of this amphibious species of the weasel family. Ranger and visitor reports have confirmed the use of most major lakes, rivers, and large streams in the park by otters, but their elusive nature has made observation of these animals difficult. Blending the goals of cinema and science, Bob Landis, a wildlife cinematographer with more than 30 years of experience in Yellowstone, and I set out to document the lives of these fascinating animals. Despite the challenges, our efforts resulted in what we believe to be an exceptional natural history film, *The Yellowstone Otters*, as well as a report to the park currently in preparation.

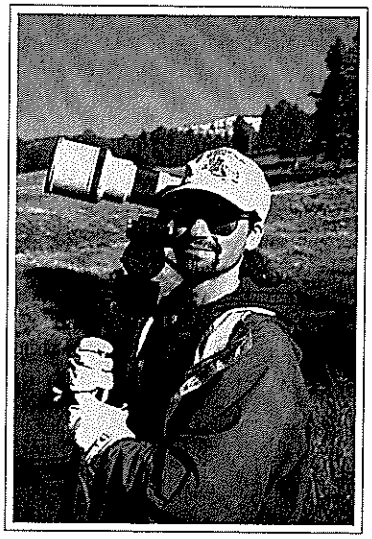
The Power of Observation

In conjunction with the production of an educational documentary film, we conducted a survey to gather general ecological data on resource utilization, movements, habitat use, and behavior of river otters in Yellowstone from April to August, 1997. Otters are, on the whole, difficult to locate. We commonly heard park visitors relate their otter experiences and end with the assumption that because *they* had seen them, otters were common. "Otters are everywhere," one person told me.

Well, otters are everywhere, until one starts looking for them, and then they are found in very few of the places one chooses to look. My approach was to search riparian corridors for otters or signs of otters including tracks, slide marks, and scats. Surveys were conducted across a variety of available park habitats that afforded easy access from roads. We searched the shorelines of slow-water stretches of the Yellowstone River, from the outlet of Yellowstone Lake through Hayden Valley to the brink of Upper Falls. We also searched the shores of the lake from Sedge Bay west and south to the West Thumb Geyser Basin. Tributaries of the Yellowstone on the northern range were surveyed, including stretches of the Lamar River, Soda Butte Creek, Slough Creek, and the Gardner River, all of which are smaller waterways with predominantly fast-moving water. The portion of the Madison River within the park was also surveyed. Some observations were made opportunistically during winter months.

Using standard methods to estimate otter abundance, we measured the quantity of otter presence through observation of individuals or sign per survey distance. When otters were located, they were observed with aid of 8-12x binoculars or a 20x-60x spotting scope. Otter pups were

Above left: Mother otter rests her eyes as pup eats fish. Below: Author in Lamar Valley. Photo by Bob Landis.



typically less than half the size of adults and always found with one or more adult females. Adult otters weigh from 7 to 9 kg (15 to 20 pounds) and can be up to 1 m (3 feet) long.

Detection and Discovery

Otters were not easily found. During the study, 451 hours were spent trying to locate and observe otters; only 15 percent (69 hours) of that time was spent observing the animals. The subjects of 98 percent (67 hours) of the observation time were two groups of otters—both females with pups, whose home ranges were restricted by brood-rearing, making it easier for us to locate them on a regular basis. General survey effort (May 11 to July 19) also reflected our poor success in finding otters: in 53 surveys of shoreline habitat totaling 188 km (113 miles), otters were found at no less than 15-km (9-mile) average intervals.

This low survey success rate may result from many factors combining in unknown proportions, and the degree to which the survey results relate to true otter abundance is unknown. It is difficult to detect animals whose secretive nature includes nocturnal activity, the use of habitats inaccessible to humans, and an ability to move a long distance in a short time.

Other studies have found otter activity patterns to be crepuscular (active around dawn or dusk) or nocturnal—our survey results supported these conclusions. We spent 18 days (187 daylight hours) with a female and her two pups (the northern range group) that were active only 30 percent (56 hours) of the time we watched them. The otters spent the remaining 70 percent within a den. On more than a third of the mornings, we arrived to find them returning to the den, as if they had been on night shift, leaving behind only the scraps from fish they had caught and fed on during the night.

If otters spend two-thirds of their average day in a den as this group did, then it's not surprising that they are not often seen during daylight surveys. These resting sites provided security and made otters difficult to find. Beaver lodges, log jams, hollow logs, bank recesses, rock recesses, and even culvert pipes were used by otters for dens.

Some den entrances were under water making them imperceptible in most situations. Were it not for the sudden appearance of an otter, I would not have discovered one such den. One evening in Hayden Valley, much to my surprise, a pup appeared only an arm's length away from me. The pup used a latrine site where scat and urine are frequently deposited (thought to be important "scent posts" in otter society) from which I was collecting scat samples. The scats, complete with fish bones and scales, were commonly found at this site along with other telltale signs including clumps of balled-up grass. After leaving me a fresh sample, the pup quickly dove back into the water and vanished beneath a subsurface bank that concealed a den!

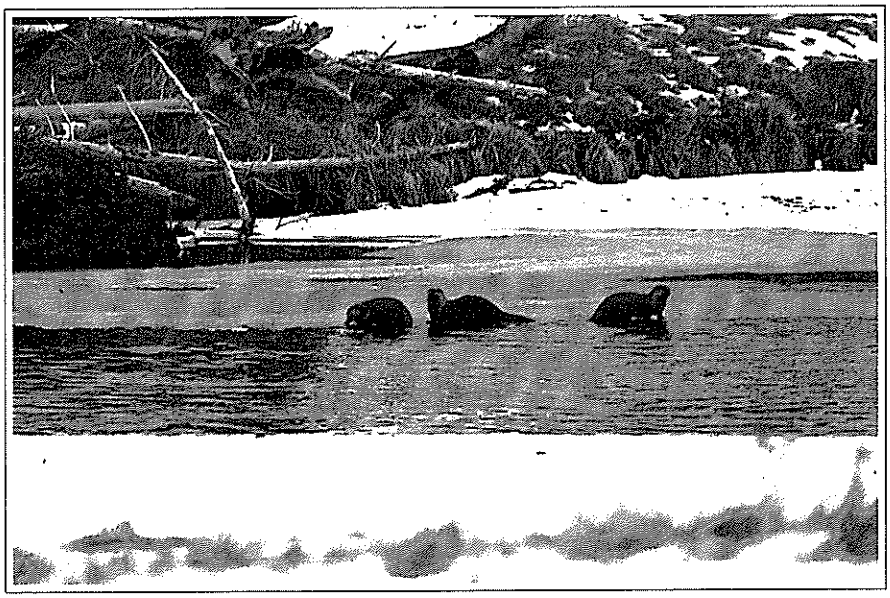
Travelers Over Water, Land, and Ice

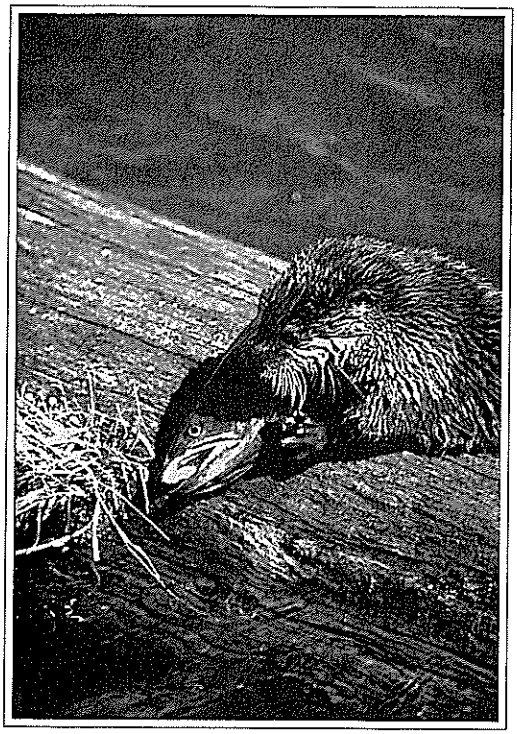
Home ranges for otters in the Rocky Mountain west vary from 8 to 78 km (5 to 47 miles) of linear shoreline distance, and within these ranges they typically travel from 2 to 5 km (1.2 to 3 miles) per day; however, much longer movements are common as we discovered. The longest distance traveled by otters observed during our survey was a group of four adult otters that swiftly descended the Yellowstone River 10 km (6 miles) from Mud Volcano to Alum Creek. They then moved upstream in the Yellowstone for a total of 12.5 km (7.5 miles) in just less than four hours. In May, we tracked another group for 22.5 km (13.5 miles) along a trail through thin ice, snow, and sand along the shore of Yellowstone Lake.

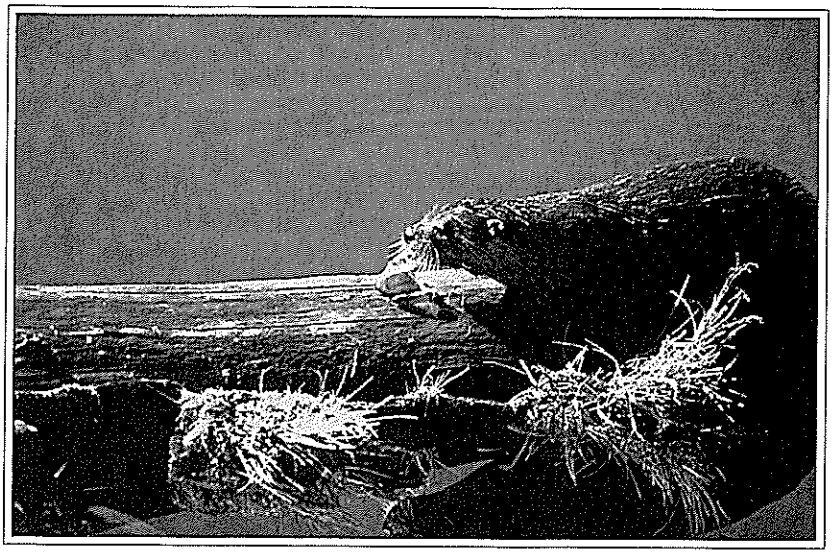
Perhaps our most interesting observation of traveling otters involved a group of four adults located on May 12 in Hayden Valley. This group traveled down the Yellowstone River 9 km (6 miles) to the brink of Upper Falls in an hour. They then traveled back up the river after being turned back at the falls because the overland route otters typically take around the falls includes a portion of the park visitors' trail to the overlook. As we watched, visitors on the overlook platform marveled at an amazing show—swimmers at the very brink of the falls! Surviving this feat, the performers moved back up the river ending their afternoon journey. Overall, we found that otters had the capability to travel remarkable distances, leading me to believe the park has just one population of otters continuous over all major waterways.

Predator and Prey

One of our primary interests was to document otter interactions with other Yellowstone animals. Otters are both predators and prey, as we had opportunities to observe. Accounts of predation attempts on otters are rare in the literature. Natural enemies of otters in Yellowstone include gray wolves, coy-







Otters are quite successful at catching fish. Mother (above) and pup (left) with large cutthroat trout. During the study, one female caught, on average, 2.5 large trout per day for 18 days. Below left: Otter family in winter. The log jam in the background was used by this family as a den.

otes, red foxes, and bobcats, all of which may prey upon otters.

We witnessed one attempt at predation upon otters on April 17, when three coyotes attacked two adult otters using an overland route near the Blacktail Ponds. The otters were caught well away from their hole in the ice and fled from the coyotes at a gallop. One otter escaped by returning to the hole while the coyotes closed in on the other. One coyote attempted bites to the otter's back, just behind the head, while another coyote came from the otter's other side. Still another coyote, perhaps a pup, was cautious and tentative and ran behind. The otter continued to try to escape by alternately fighting and running. When surrounded by the coyotes, it rolled to its back where it would seem to be more vulnerable; however, from this position it was able to lunge swiftly and accurately, biting a coyote's muzzle at least once. In the end, the otter appeared to have escaped—though blood on the coyote's muzzle suggested the encounter had consequences for the otter, the coyote, or both.

Coyotes and otters interacted frequently, but we saw no other interactions that appeared to have been predation attempts on the otters. Particularly in winter, we often saw coyotes monitor the activities of otters perhaps for the opportunity to steal fish. Feeding otters often attracted other scavengers as well, including bald eagles, ravens, and even pelicans. Most of the attempts to take fish from otters that we witnessed were unsuccessful; furthermore, after successful attempts the otters replaced their loss quite quickly. In early May, an otter was fishing in a flooded side channel of the Yellowstone River and came up through a slushy layer of ice with a medium-sized trout. A bald eagle had been watching the fishing otter from a perch 200 m (700 feet) away and flew at the otter. The eagle swooped in low and fast, scaring the otter which had just come through the slush. Surprised by the eagle, the otter ran out of the hole at a quick burst. The eagle banked and landed near the hole, waited a minute, then hopped over to the hole and onto the trout. After three dives, the otter caught a sucker and ate it only 40 m (131 feet) from where the usurper perched with a second eagle who had joined the first in eating the trout. The observation suggested that the otters' hunting success rate could accommodate such losses to scavengers.

Factors Limiting Otters?

The hunting success rates of otters have not been well documented. In our study, 38 to 62 percent (lake and inlet, respectively) of one female otter's dive attempts ($n = 84$) resulted in catching a fish, while 40 percent of the dives of another female ($n = 18$) resulted in a successful catch. These rates compare roughly to values found elsewhere for otter predation, and in contrast with the capture success rates of other carnivores, are quite successful.

Studies have shown that otters generally exhibit disproportional selection for such slower-moving, bottom-dwelling prey as crustaceans, sculpins, and suckers. The predominance of faster-moving trout as available prey in Yellowstone has been suggested as a factor that may limit the abundance of otters. This assumes that otters have difficulty in capturing trout, which did not appear to me to be the case.

The otters' relationship with their prey poses some interesting questions. With Yellowstone's world-renowned trout population we might expect an otter population to be equally robust. Perhaps prey availability is not a factor that stands alone in determining otter numbers. The predator-prey relationship may be more complicated by local prey abundance only during summer, when mothers are rearing their pups. After the emergence of pups from the den, a brood-rearing female occupies habitats with the resources she needs to raise her dependent,

less-mobile pups. In our observations, a female raising a pup used a restricted home range of 5 km (3 miles) linear shoreline distance where otter habitat was exemplary: calm, slow waters with seclusion, secure dens, and abundant prey. A different female caught, on average, 2.5 large trout per day for 18 days within a core area of 2 km^2 (0.77 mi^2).

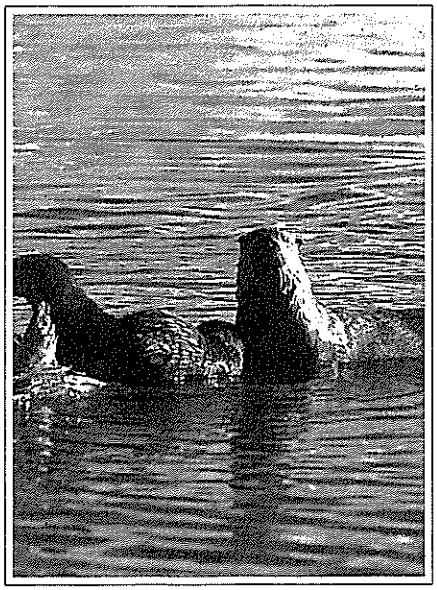
Riparian Neighbors

A strong association between beaver and otter occupation has been well documented in other areas. In addition to providing good den sites, beavers can alter riparian areas by building dams that form productive pond habitats preferred by otters and their prey. The relationship between beavers and otters may occasionally extend to sharing the same den! A few years ago a Yellowstone ranger reported seeing several beavers near a lodge on a pond near the Snake River. Several days later, he reported with some chagrin that there was a family of otters swimming in and out of the beaver lodge; yet, he was certain he had correctly identified the animals seen earlier as beavers. He was relieved when told that, though he did not find the species together, river otters' use of occupied beaver lodges is well documented in scientific literature.

Few beavers inhabited our survey areas, and we encountered no beavers while searching for otters. However, three abandoned beaver lodges along the Yellowstone River still serve as frequently used otter dens.

Otter Society

In many species, social interactions effectively limit population growth, but few reports exist concerning social strife among otters in the wild. Long, linear home ranges of otters frequently overlap to form a non-territorial, spatial distribution. Within these overlapping home ranges, activity centers associated with dens, landings (sites where otters often come to shore), and latrines are found. For example, otter movements in Hayden Valley and Lamar Valley seemed to begin and end at predictable locations such as certain beaver lodges or logjams, respectively. Their frequency of use suggested that otters had a traditional or learned use of these sites.



Mother and pup rest on partially submerged log. Logs, which are safe from many predators, are often used as secure places to eat fish.

Traditional use of a den or landing and the associated latrine may serve as a communication network in which scats, urine, and anal gland secretions advertise the presence of individuals. Melquist and Hornocker (1983) wrote in their landmark monograph:

> "scent marking may be a form of covert aggression, but it would not prevent [other otters] from using a particular area...the individual and the current space is defended without reference to fixed spatial boundaries."

They reported that while there is no defense of a site, there is defense of the space currently occupied. This strategy may well serve a population of highly mobile carnivores confined to long, narrow home ranges. Our only glimpse into this world occurred along the Yellowstone River on June 27, when four otters entered the occupied den of a female with a pup. No indications suggested that the meeting was hostile; rather, the four emerged several hours later and traveled down the river. The female and her pup, appearing unharmed, left the den minutes later and did not return in the following days. While difficult to interpret, communications may have taken place in this exchange that address aggression, tolerance, and avoidance within the society of otters. Unfortunately, we were unable to observe what occurred within the den.

The Status of Yellowstone's Otters

Initially, we perceived an apparent scarcity of otters. Then, as we slowly became familiar with their elusive nature, we reconsidered and felt perhaps they may not be scarce, just hard to find. In the end, the question remained unanswered. To get at it further, the factors that determine otter abundance need to be studied further. While observing and documenting otter behavior, we found little to directly contribute to an understanding of this critical aspect of ecology, but we could speculate on which factors might be involved; prey relationships, habitat quality, and social interactions seem worthy of investigation.

Factors explaining population regulation in otters are largely unknown elsewhere, as well. In most documented cases, otter mortality was heavily influenced by human-related factors including trapping, road kills, and illegal kills. In the protective sanctuary of the park, these mortality sources would theoretically be less consequential. If this is true, Yellowstone offers us a good opportunity to study otters under natural conditions and to further delve into the enigmatic world of the water weasel.

Literature Cited

Melquist, W.E. and M. G. Hornocker. 1983. Ecology of River Otters. Wildl. Monogr. 83:1-60.

Nathan Varley has lived in Yellowstone Park for more than 20 years. In 1994, he earned a M.S. in Fish and Wildlife Management at Montana State University, studying mountain goat ecology in the Absaroka Range. Since then he has worked with a variety of wildlife species including wolves, moose, and otters. More recently, he has been instrumental in the creation of a biological consulting company which specializes in ecological research, filming, and interpretive enterprises in Yellowstone.

Draft Report Released on Brucellosis Science

In December 1997, the NPS welcomed the release of a draft National Academy of Science (NAS) report on brucellosis in bison and elk in the greater Yellowstone area (GYA). The review was commissioned last May by the Department of Interior to evaluate existing science related to the concern that bison or elk could transmit the bacteria *Brucella abortus* to cattle. The organism can cause the disease brucellosis in cattle, which often results in abortions by infected animals. A vigilant national regulatory effort has reduced the number of infected cattle herds in the United States; the goal of the national brucellosis eradication program, developed cooperatively by the states and the Animal and Plant Health Inspection Service (APHIS), is eradication of the disease from cattle by 1998. The disease can affect humans, but as the NAS report states, "human brucellosis is not a widespread health threat today in North America."

The NAS review determined that eradication of brucellosis from wildlife in the GYA is not now technically feasible. But studies were identified which could lead to the development of techniques to make eradication a real possibility in the future. The primary finding in the report is that risk management is critical to controlling the disease in the GYA until a proven, effective vaccine and a practical delivery mechanism for inoculating elk and bison are found. The report emphasized that brucellosis affects both elk and bison and encompasses the entire GYA, not simply Yellowstone National Park; the authors stated that "it would be impossible to vaccinate all GYA elk."

Efforts to address brucellosis in wildlife have intensified in recent years, as the disease in cattle has diminished radically. The states of Montana, Idaho, and Wyoming have been working with the NPS (especially Yellowstone and Grand Teton national parks), other land-management agencies, and several research agencies to determine how to protect the cattle industries while sustaining, wild, free-ranging herds of bison and elk in the GYA. A Greater Yellowstone Interagency Brucellosis Committee is working to secure funding for continued brucellosis research and related planning and management activities.

A final version of the NAS report will incorporate questions and comments from the Interior agencies that commissioned the study.

Wolf Population Growing

As of January 15, 1998, there were at least 85 gray wolves in the greater Yellowstone population, including 22 adults, 15 yearlings, and 48 pups less than 1 year old. Free-ranging wolves made up 9 packs, and 4 wolves remained temporarily penned following an incident of livestock depredation last fall; plans are to release the captive wolves in the spring. The largest family continued to be the Rose Creek pack, which numbered 15 wolves living in the western part of the Lamar Valley, although recently it appeared that 2 wolves dispersed from the group. U.S. Fish and Wildlife Service agents are investigating the illegal shootings of 2 males from the Druid Peak pack in December 1997; the incidents occurred east of Yellowstone.

Also in December, U.S. District Court Judge William Downes found that the wolf reintroduction program in Yellowstone and central Idaho violated the intent of section 10(j) of the Endangered Species Act because of the lack of geographic separation between fully protected wolves already existing in Montana and the reintroduction areas in which special rules for wolf management apply. The judge wrote that he was "especially mindful of the concerted efforts of the Government and wolf-recovery advocates to accommodate the interests of stockgrowers and others who may be adversely affected by the wolf recovery program," and reached his decision "with the utmost reluctance." He ordered the removal of reintroduced wolves and their offspring from the Yellowstone and central Idaho experimental population areas, but immediately stayed his order pending appeal. The Department of the Interior asked the Justice Department to appeal the case, and an appeal was filed with the Tenth Circuit Court of Appeals on February 6, 1998. Meanwhile, until a final court order is issued, wolves will be protected and managed just as they have been.

In January 1998, park staff arranged for Helicopter Wildlife Management to capture and radiocollar 17 wolves from 5 packs as part of long-standing plans to continue monitoring the progress of the recovery effort. The capture operations were completed without injury to either human handlers or wolves. Helicopter Wildlife Management donated the equipment, personnel, and helicopter time used to net-gun the wolves, and radio collars were purchased with private donations. Another attempt to collar wolves from the remaining packs will occur in March.

Photo courtesy William Campbell.

Cascade Geyser Rejuvenates

An old tourist pleaser from the last century, Cascade Geyser—located in the Upper Geyser Basin not far from Old Faithful—rejuvenated on January 9, 1998. It began several hours after a small earthquake just one mile away, which appeared to trigger an eruption of another major geyser, Giantess. Though Giantess' eruptions typically last for days, this one aborted after just three hours, and Cascade began dumping chocolate-brown water into the nearby Firehole River. The geyser quickly cleaned its throat and subsequent eruptions, visible from Old Faithful, have been spouting 10 meters (30 feet) tall about every six minutes. Cascade Geyser has a history of erupting for short periods of time, especially after earthquakes, but it had not

been observed at all since 1992 when it "burped" once to a height of about one meter. Eruptions to its full height hadn't been seen since before 1912.

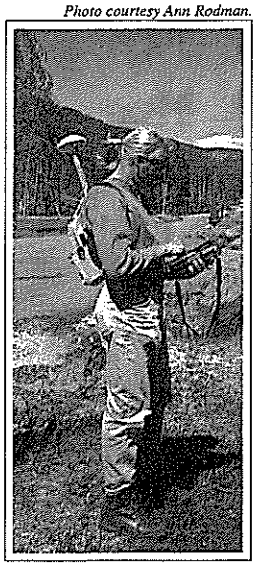
IGBST Gets New Leader

Beginning in February 1998, the Interagency Grizzly Bear Study Team (IGBST) will have a new leader. Dr. Chuck Schwartz, formerly a research coordinator with the Alaska Department of Fish and Game, arrived to replace the retired Dick Knight (*see interview, this issue.*) Schwartz has been director of the Moose Research Center and leader of an interagency team studying brown bears on the Kenai Peninsula. He has expertise in black and brown bear ecology and management, ungulate physiology and nutrition, predator-prey dynamics, and population management. He envisions continuing the ongoing research with additional emphasis toward a systems approach to studying grizzly bears in greater Yellowstone.

Celebrating "People and Place"

More than 225 persons attended Yellowstone's fourth biennial science conference on "People and Place: The Human Experience in Greater Yellowstone," held October 12-15, 1997, in Mammoth Hot Springs. Highlights of the conference included author T.H. Watkins discussing the difficulties with consensus during the A. Starker Leopold Lecture; professor Donald Worster speaking on a comparative perspective of the conservation movement in North America for the Superintendent's International Luncheon; and a humorous evening talk by Patricia Nelson Limerick on "Lessons and Lesions of History: Yellowstone and Progress." Retired park historian Aubrey L. Haines was present for the first lecture in his honor, in which U.C.L.A.'s Peter Nabokov discussed "Reintroducing the Indian: Observations of a Yellowstone Amateur." Abstracts from the conference are available by calling (307)344-2203 or via email: Tami_Blackford@nps.gov

Photo courtesy Ann Rodman.



Park Staff Test GPS Accuracy

Global Positioning Systems (GPS) are increasingly touted for use in research and mapping projects. Staff from Yellowstone's Spatial Analysis Center recently conducted their own accuracy tests on GPS units available in the park. They chose test locations to represent the best and worst possible conditions under which measurements are taken in the park. Three readings were taken at each of three survey sites (two "ideal" sites and one "bad" location), using the park's TotalStation, a traditional survey instrument that measures accuracy to no less than one centimeter. The overall results were reported to be very positive. In fact, errors were less than expected; in particular, the measurements taken under forest cover (much of the park) were generally satisfactory, although the researchers caution that the maximum error of approximately 9 meters, taken under heavy forest canopy, is not much better than digitizing from a 1:24,000 U.S.G.S. topographic map. Satellite orientation, selective availability, atmospheric conditions, surface reflectance, and distance between a known base station and the GPS unit used may all affect the accuracy of field measurements. In the future, the park hopes to provide additional training and access to GPS units to its scientists and resource managers.

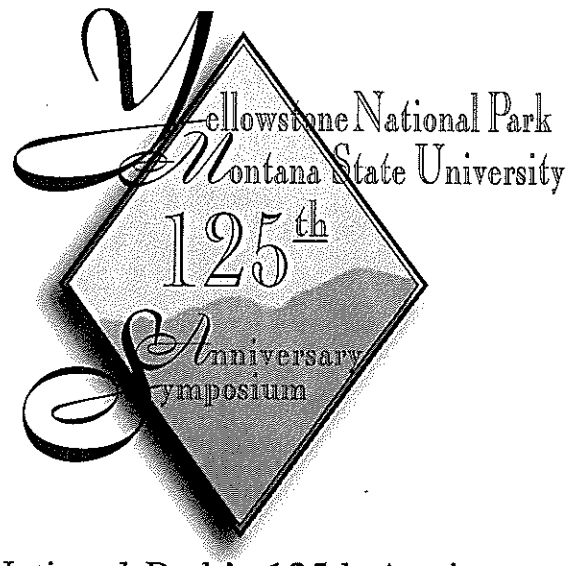
Archeological Research Reveals New Information

During the 1997 field season, park staff, cooperators, and volunteers contributed to park archeology studies and made a number of new discoveries. The general patterns of obsidian use are beginning to emerge through determination of the sources of obsidian found in a variety of locations. For example, along the Yellowstone River upstream from Gardiner, Obsidian Cliff obsidian dominates the samples sourced so far, but Bear Gulch obsidian from southern Idaho is present in minor amounts. The obsidian in the gravels at Park Point, on the east shore of Yellowstone Lake, is from an unknown source. As more samples are taken, the researchers hope to determine if distinct patterns of obsidian use can be identified for people at different times in the past.

Along the Yellowstone River corridor, data from three eroding roasting pits/hearths were salvaged and two other sites were tested. All the sites were prehistoric in age and had been severely damaged by the 500-year floods that occurred earlier in the summer. One site contained Intermountain ware (radiocarbon dated at A.D. 1320±70 yrs.) from the most recent period of prehistoric occupation. This is only the second prehistoric ceramic site identified in the park.

A historical archeology crew led by Ken Karzmiski from the Museum of the Rockies tested the Soda Butte Soldier Station along the Northeast Entrance road. When the Army managed Yellowstone, there were 16 such posts throughout the park. The archeology work, in combination with archival data, is clarifying the chronology and function of select features at the site.

Of particular interest is the discovery of very young bison calf bones at a Lamar Valley site. A radiocarbon age of 2480±70 years B.P. was obtained using a bison ulna. This is the first archeologic site in the park that clearly shows occupation during a particular season, based upon the timing of bison calving activity in late spring.



Yellowstone National Park's 125th Anniversary Symposium

May 11 - 24, 1998, at Montana State University
Bozeman, Montana

A two-week symposium commemorating 125 years of Yellowstone National Park's influence on scholarly research and creative activities will be held at Montana State University, Bozeman, Montana, and is designed to attract an international audience of world class researchers. The goal of the symposium is to highlight the interplay between universities, natural areas such as Yellowstone, and humankind.

Conferences include:

National Parks in the Global Ecosystem
The Greater Yellowstone GEO-Ecosystem; An Integrated View of Geology and Biology
Life in Extreme Environments
Fire and the Yellowstone Ecosystem: Ten Years of Study and Change

Workshops include:

The Greening of Yellowstone
The Greater Yellowstone Data Clearinghouse: A Paradigm for Sharing Information
Biosphere-Geosphere Linkages in Yellowstone: Defining a New Generation of Ecosystem Research in Greater Yellowstone

Field Trips include:

Two days in Yellowstone National Park in conjunction with
"The Greater Yellowstone GEO-Ecosystem, An Integrated View of Geology and Biology"
One day in the park in conjunction with "The Greening of Yellowstone"
One day in the park in conjunction with "Fire and the Yellowstone Ecosystem"

Exhibits include:

Art, Photography, Library documents exhibits, and a Film Series
Other: Concerts, Black Tie Ball,
Special Opening and Closing ceremonies at MSU and at Old Faithful,
Yellowstone National Park, with many distinguished speakers.

For further information: Carolyn Manley, Conference Coordinator,
Mountain Research Center, Montana State University,
PO Box 173490, Bozeman, MT 59717
406/994-5145
email: carolyn@peak.mrc.montana.edu
www.mrc.montana.edu/YNP_125